OPERATION BOOK

for

MODEL CRB-8 COMPLEX RATIO BRIDGE

Manual No. 1-500783-027

Rep. 9/70

THE SINGER COMPANY
ELECTRONICS PRODUCTS DIVISION
GERTSCH OPERATION

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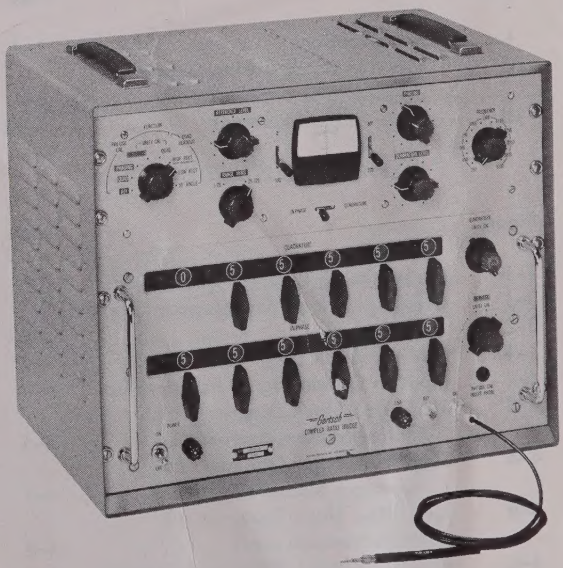

Figure 1-1. Model CRB-8 Complex Ratio Bridge

SECTION I
GENERAL DESCRIPTION

1-1. PURPOSE.

1-2. The Gertsch Model CRB-8 Complex Ratio Bridge measures phase and amplitude relationships between the input and output signal voltages of a unit under test. The signals are compared and their relationships are indicated either as a complex vector ratio (± in-phase ratio ± quadrature ratio) or as an in-phase ratio plus phase angle directly in degrees.

1-3. DESCRIPTION.

1-4. The bridge uses the input signal of the unit under test as a reference voltage and the output of the unit under test as a signal input. With the reference voltage operating as a source, an internal voltage is selected by a six decade ratiotran. When the internal voltage exactly equals the signal input voltage, a phase sensitive null detector, operating on an AC bridge principle, indicates a null. A null amplifier, consisting of a tuned preamplifier and a high gain amplifier, drives the null detector circuit so that minute values of off-null voltage can be detected. At null, the setting of the ratiotran indicates the in-phase ratio between the two input signals.

1-5. Any phase shift through the unit under test introduces a quadrature component into the output signal which can cause erroneous measurements by obscuring the in-phase null point. To eliminate this effect, a second ratiotran is used to null out the quadrature component. A portion of the reference voltage is shifted through 90° and operates as the source for this ratiotran. At null, the setting of this ratiotran indicates either the quadrature ratio or the phase angle.

1-6. Harmonic voltages and noise, generated by the unit under test, can also obscure the null. The tuned preamplifier of the null amplifier reduces the noise and harmonic components of the null voltage to a minimum. The noise and harmonic content of the input signal can be measured at a special connector, accessible from the back of the unit.

1-7. To indicate complex ratios or phase angles in all four quadrants, two switches are provided. One switch allows the in-phase portion to be inverted for measurements in the second and third quadrants. The second switch allows the quadrature portion to be inverted for measurements in the third or fourth quadrants. Through proper selection of switch positions, the complex vector ratio or phase angle can be determined regardless of phase differences between the reference and signal voltages.

1-8. Through the use of front panel tuning controls, the bridge can be tuned to any frequency in the 360 to 5100 cps range. No plug-in filters or networks are used.

1-9. Isolation of the unit under test is accomplished by an isolation amplifier which produces an input impedance of at least 20,000 megohms at null. This feature virtually eliminates loading errors and ground loop problems. To further reduce ground loop problems, the signal circuits may be completely isolated from case ground.

1-10. The ratio bridge is a self-contained unit which can be mounted in a standard Gertsch carrying case or fitted into a standard 19 inch relay rack. The unit may be converted for use with 115 or 230 vac power by simply operating a switch and replacing a fuse.

1-11. All operating controls, indicators, and test connectors are mounted on the front panel. No auxiliary equipment is required for pre-use adjustments or operation.

TABLE I. SPECIFICATIONS

FREQUENCY RANGE:
350 to 5100 cps continuous

ACCURACY:
Inphase
Rectangular Positions

$$\text{Reading} \pm \frac{f}{400}\left[0.00003 + 0.005(\text{quad ratio})\right]$$

Angular Position

$$\text{Reading} \pm \frac{f}{400}\left[0.00003 + 0.0001(\Theta)\right]$$

Quadrature
Rectangular Positions

$$\text{Reading} \pm \left[\frac{f}{400}(0.0005) + 0.001(\text{quad ratio})\right]$$

Angular Position

$$\text{Reading} \pm \left[\frac{f}{400}(0.03) + 0.005\ (\Theta)\right]$$

Θ = measured angle in degrees

f = signal frequency in cps

RANGE:

Inphase Ratios:	0.000000 to 1.11111
Quadrature Ratios:	
Rectangular High	0.00000 to 0.50000
Rectangular Low	0.00000 to 0.10000
10° Angle	0.00000° to 10.000°

REFERENCE VOLTAGE:
2 Ranges:
5 - 25 V RMS
25 - 125 V RMS

SENSITIVITY:
Null Detector 10 uv

PROBE INPUT IMPEDANCE:

At null:	20,000 megohms + 0.01 pf
Off null:	1 megohm min. + 100 pf

INPUT POWER:
115/230 VAC, 50-400 cps, 70 VA

SIZE:

Cabinet:	19-1/2"W x 16-1/2"H x 13"D
Rack:	19"W x 14"H x 12"D

SECTION II
INSTALLATION

2-1. GENERAL.

2-2. The ratio bridge is shipped completely assembled and ready for operation. The only installation required is connection to a power source. Normally the unit is shipped for 115 vac power. To convert to 230 vac power, refer to paragraph 2-3.

2-3. POWER CONVERSION.

2-4. To convert the unit for 230 vac power, proceed as follows:

a. Turn the 115/230 switch (located on the back of the unit) to the 230 vac position.

b. Replace the 3/4 amp AC power fuse with a 3/8 amp fuse.

SECTION III
OPERATING INSTRUCTIONS

3-1. GENERAL.

3-2. The Model CRB-8 may be operated in any one of three modes depending on the accuracy required of the quadrature reading and the phase shift through the unit under test.

a. With the FUNCTION switch in the HIGH RECT position, the bridge will measure quadrature ratios up to 0.50000 (signal to reference input) with maximum accuracy. With an in-phase ratio of unity, the bridge can measure phase shift angles as high as 25°. For in-phase ratios of less than unity, larger phase shift angles can be measured as shown in figure 3-1.

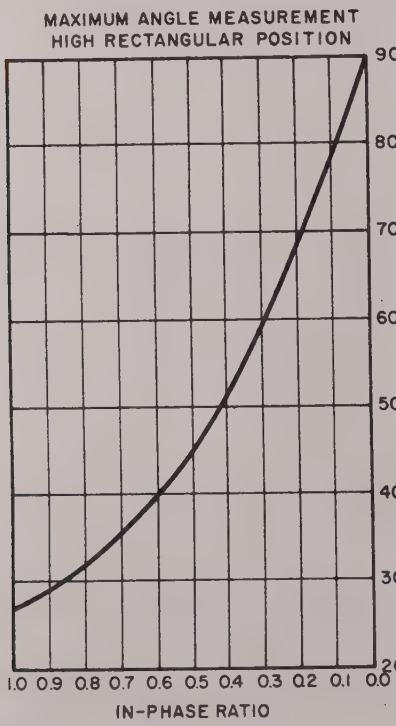

Figure 3-1. Maximum Angle Measurement Graph

b. With the FUNCTION switch in the LOW RECT position, the bridge will measure quadrature ratios up to 0.10000 with maximum accuracy. With an in-phase ratio of unity, the bridge can measure phase shift angles as high as 5°. For in-phase ratios of less than unity, larger phase shift angles can be measured.

c. With the FUNCTION switch in the 10° ANGLE position, the bridge will indicate phase shift angles of up to 10° directly in degrees. Since the indicated angle is based on the assumption of a linear tangent function, the accuracy of the indicated angle is necessarily limited. See figure 3-2 for a graph of the error due to actual non-linearity of the tangent function.

3-3. In any of the three positions, the bridge can measure the in-phase ratio with approximately the same accuracy. The quadrature component of the signal input can obscure the in-phase ratio null but as long as the quadrature component is nulled out a precise in-phase ratio can be measured.

3-4. The functions of the operating controls are described in Table II.

NOTE

Pre-operation adjustments consist of turning the FUNCTION switch through the first five positions, locating the control which is color-coded to match the switch position, and adjusting that control to obtain a null on the self-contained meter. No additional test equipment is required.

3-5. PRE-OPERATION ADJUSTMENTS.

3-6. Before operating the bridge and whenever the reference voltage or frequency is changed, adjust as follows:

a. Make certain power cord is connected to a power source.

b. Turn POWER switch on and allow approximately five minutes for the instrument to warm up.

c. Determine approximate frequency of the reference input.

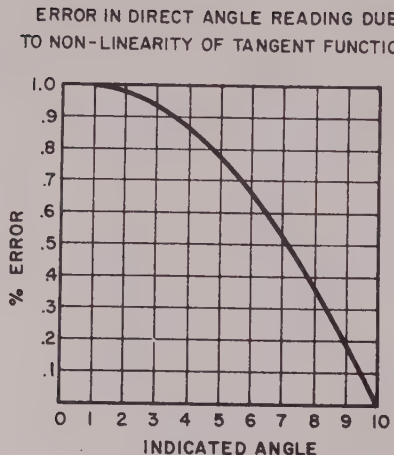

Figure 3-2. Error Graph

d. Turn FREQUENCY switch to the range which covers the frequency of the reference input.

e. Connect reference voltage to the REF connector. ≥3.0 V

f. Connect probe cable assembly to the SIG connector.

g. Insert probe of probe cable assembly into the PRE-USE CAL jack.

h. Turn FUNCTION switch to the REF position.

i. Turn RANGE switch to the low range position.

j. Adjust REFERENCE LEVEL switch and VERNIER control to obtain zero center indication on the meter. If null cannot be obtained, turn RANGE switch to the high range position and repeat procedure.

k. Turn FUNCTION switch to the QUAD position.

l. Adjust QUADRATURE LEVEL switch and VERNIER control to obtain zero center indication on the meter.

m. Turn FUNCTION switch to the PHASING position.

Go to 3-10

TABLE II. FUNCTIONS OF OPERATING CONTROLS, INDICATORS, AND CONNECTORS

PANEL MARKING	TYPE OF CONTROL	FUNCTION
FUNCTION	8 position rotary switch	In the REF position, switches circuitry so that the in-phase detector reference voltage can be metered and set to the proper operating level.
		In the QUAD position, switches circuitry so that the quadrature detector reference voltage can be metered and set to the proper operating level.
		In the PHASING position, switches circuitry so that any phase shift through the null amplifier can be compensated for.
		In the IN-PHASE position, switches circuitry so that any gain variations in the vector summing circuitry can be compensated for.
		In the QUAD position, switches circuitry so that any phase shift in the vector summing circuitry can be compensated for.
		In the HIGH RECT position, switches circuitry for in-phase and quadrature ratio measurements. The maximum measurable quadrature ratio is 0.50000 and

TABLE II. FUNCTIONS OF OPERATING CONTROLS, INDICATORS, AND CONNECTORS (cont)

PANEL MARKING	TYPE OF CONTROL	FUNCTION
FUNCTION (cont)		the quadrature reading must be divided by two to obtain the ratio. See figure 3-1 for the relationship between in-phase ratio and maximum measurable phase angle.
		In the LOW RECT position, switches circuitry for in-phase and quadrature ratio measurements. The maximum measurable quadrature ratio is 0.10000 and the quadrature ratio is direct reading. With a unity in-phase ratio, the maximum measurable phase angle is 5°.
		In the 10° ANGLE position, switches circuitry for in-phase ratio measurements and direct reading phase angle measurements. The maximum measurable phase angle is 10°. See figure 3-2 for an error graph of the direct angle reading.
REFERENCE LEVEL and RANGE	11 and 2 position rotary switches and VERNIER potentiometer	The three controls set the reference voltage circuitry to the amplitude level of the reference input.

TABLE II. FUNCTIONS OF OPERATING CONTROLS, INDICATORS, AND CONNECTORS (cont)

PANEL MARKING	TYPE OF CONTROL	FUNCTION
0° - 180°	2 position lever switch	Allows in-phase reference voltage to be inverted for measurements in the second and third quadrants.
90° - 270°	2 position lever switch	Allows quadrature reference voltage to be inverted for measurements in the third and fourth quadrants.
IN-PHASE QUADRATURE	2 position lever switch	Selects reference voltage input to null detector. With switch in IN-PHASE position, the null detector reacts to the in-phase component of the signal input voltage. With the switch in QUADRATURE position, the null detector reacts to the quadrature component of the signal input voltages.
	Meter	In the first two positions of the FUNCTION switch, the meter operates as a voltmeter to indicate reference voltage levels. In the remaining positions, indicates null points for adjustments and ratio settings.
PHASING	11 position rotary switch and VERNIER control	Operates as coarse and fine adjustment to tune the preamplifier.

TABLE II. FUNCTIONS OF OPERATING CONTROLS, INDICATORS, AND CONNECTORS (cont)

PANEL MARKING	TYPE OF CONTROL	FUNCTION
QUADRATURE LEVEL	11 position rotary switch and VERNIER control	Operates as coarse and fine adjustment of the quadrature generator voltage output.
FREQUENCY	10 position rotary switch	Sets the bridge to the frequency range of the signal and reference input voltages.
QUADRATURE (ratio)	Five 11-position rotary switches	Control quadrature component of reference voltage. With the FUNCTION switch in the HIGH or LOW RECT position, the setting of the ratio controls indicates the quadrature ratio between the signal and reference voltages. With the FUNCTION switch in the 10° ANGLE position, the setting of the ratio controls indicates the phase angle of the signal voltage.
IN-PHASE (ratio)	Six 11-position rotary switches	Controls in-phase component of the reference voltage. The setting of the ratio controls indicates the in-phase ratio between the signal and reference input voltages.

TABLE II. FUNCTIONS OF OPERATING CONTROLS, INDICATORS, AND CONNECTORS (cont)

PANEL MARKING	TYPE OF CONTROL	FUNCTION
IN-PHASE UNITY CAL	10 position rotary switch and VERNIER potentiometer	Adjusts reference circuitry to compensate for variations in gain through the summing circuitry.
QUADRATURE UNITY CAL	2 position rotary switch and potentiometer	Adjusts reference circuitry to compensate for phase shift in the summing circuitry.
PRE-USE CAL	Jack	Convenience jack for connecting the signal input to unity ratio or to a phasing signal during pre-operation adjustments.
REF	Triaxial connector	Input connector for the reference voltage used to obtain and indicate a complex ratio.
SIG	Triaxial connector	Connector for signal input voltage from the probe.
1.5A	Fuse	Series fuse for reference voltage input circuit.

TABLE II. FUNCTIONS OF OPERATING CONTROLS, INDICATORS, AND CONNECTORS (cont)

PANEL MARKING	TYPE OF CONTROL	FUNCTION
POWER	ON-OFF switch	Input power on-off switch
	Fuse	Input power circuit fuse
J201	BNC connector	Connector for measuring noise and harmonics.

n. Adjust PHASING switch and VERNIER control to obtain zero center indication on the meter.

o. Turn FUNCTION switch to the UNITY CAL IN-PHASE position.

p. Adjust UNITY CAL IN-PHASE switch and VERNIER control to obtain zero center indication on the meter.

q. Turn FUNCTION switch to the UNITY CAL QUAD position.

r. Adjust UNITY CAL QUADRATURE switch and potentiometer to obtain zero center indication on the meter.

s. Rotate FUNCTION switch through all PRE-OPERATION CAL positions and check that meter indicates zero at each position. If required, readjust controls to obtain zero indication.

3-7. OPERATION.

3-8. To measure the complex ratio between the signal and reference inputs, proceed as follows:

a. Adjust bridge to reference input as outlined in paragraph 3-6.

b. Turn 0° - 180° switch to 0°.

c. Turn 90° - 270° switch to 90°.

d. Set all IN-PHASE and QUADRATURE ratio controls to the 0 ratio position.

e. Set FUNCTION switch to desired position: HIGH RECT, LOW RECT, or 10° ANGLE.

f. Disconnect probe from PRE-USE CAL jack and connect to signal input source.

g. Turn IN-PHASE QUADRATURE switch to the IN-PHASE position.

h. Check that pointer of null meter deflects to the left (facing) of the center null position. If meter deflects to the right, turn 0° - 180° switch to the 180° position.

i. Adjust IN-PHASE ratio controls to obtain null on meter. See paragraph 3-9 for complete nulling technique.

j. Turn IN-PHASE-QUADRATURE switch to the QUADRATURE position.

k. Check that pointer of null meter deflects to the left (facing) of the center null position. If meter deflects to the right, turn 90° - 270° switch to the 270° position.

l. Adjust QUADRATURE ratio controls to obtain null on meter.

m. Repeat steps g through l.

n. Read the in-phase ratio (RX) from the control settings of the IN-PHASE ratio controls.

o. With the FUNCTION switch in the HIGH RECT position, divide the control setting of the QUADRATURE ratio controls by 2 to obtain the quadrature ratio (RjY). With the FUNCTION switch in the LOW RECT position, read the quadrature ratio directly from the control setting of the QUADRATURE ratio controls. The readout of the bridge is in rectangular coordinates and therefore the phase angle of the signal input can be determined. Since the angle has a tangent of $\frac{RjY}{RX}$ compute the tangent and refer to a standard trigonometric table to find the angle.

p. With the FUNCTION switch in the 10° ANGLE position, read the phase angle from the control settings of the QUADRATURE ratio controls.

NOTE

For each position of the FUNCTION switch, the correct placement of the decimal point is indicated by an indicator light.

q. The indicated phase angle (Θ) is deviation from 0° or 180°. To determine the actual phase angle or quadrant, refer to Table III.

3-9. NULLING TECHNIQUE. Although a variety of methods may be used to obtain a null, the surest method when starting from 0 is as follows:

a. Turn the IN-PHASE-QUADRATURE switch to the IN-PHASE position.

b. Rotate the first decade switch (left hand) of the IN-PHASE ratio controls until the meter deflects to the right of center null (overnull). Then rotate the switch back (counterclockwise) one step (under null or at null).

c. Turn the IN-PHASE-QUADRATURE switch to the QUADRATURE position.

d. Operate the first decade QUADRATURE switch as in step b.

e. Proceed with the nulling technique in an alternate manner: 2nd decade in-phase, 2nd decade quadrature, 3rd decade in-phase, 3rd decade quadrature, 4th and 5th decade in-phase.

f. Obtain final null with the sixth decade in-phase and the fifth decade QUADRATURE switch.

g. Since null points may be obscured during the nulling process, always check deflection of the null meter when the IN-PHASE-QUADRATURE switch is switched. If the meter deflects to the right, the previous decade should be stepped back one step. If all previous decades are at 0, turn either the 0° - 180° switch (in-phase) or the 90° - 270° switch (quadrature) to the alternate position.

3-10. BEFORE FILTER OUTPUT CONNECTOR J201.

3-11. To measure the noise and harmonic components of the input signal, proceed as follows:

NOTE

A K factor, determined in steps a through f, must be applied to any signal measured at connector J201.

a. Connect a VTVM to connector J201. The connector is located on the isolation amplifier chassis and is available from the back of the unit.

b. Adjust the bridge as outlined in paragraph 3-6.

c. Make certain all IN-PHASE and QUADRATURE ratio controls are at zero.

d. Apply a signal of a known amplitude (fundamental plus noise and harmonics). Do not exceed an amplitude of 2.5 vrms.

e. Carefully measure the amplitude of the signal present at connector J201.

f. Divide the input signal by the signal at connector J201 to obtain the K factor.

g. During tests, multiply any signal measured at connector J201 by the K factor.

NOTE

Any signal in excess of 1.25 vrms cannot be measured accurately. At approximately 1.25 vrms, the amplifier is driven to a non-linear point.

h. To measure noise, harmonics, and quadrature as a composite voltage, first null out the bridge and then return all QUADRATURE ratio controls to zero.

3-12. ISOLATION SWITCH.

3-13. The isolation switch, located on the back of the unit, may be used to isolate the signal common from the power supply ground. When the switch is turned to the GND position, the signal common is connected to the case and the case is at power supply ground. When the switch is turned to the ISOLATED position, the signal common is isolated from the case.

a. For most applications, the switch should be turned to the GND position. If the power supply and reference supply do not have a common external ground somewhere in the test system, large potential differences can develope. The large potentials can be radiated into the system through the case and cause erroneous indications.

b. If ground loop problems are suspected, turn the switch to the isolated position. Particularly with long cable runs, the various external grounds may have slightly different potentials and therefore offer alternate ground return paths. The voltage differentials can cause erroneous indications.

3-14. NOTES ON OPERATION.

3-15. Make certain that the reference input voltage does not contain a dc component. DC currents of more than a few microamperes will cause saturation of the ratiotran input windings. If dc voltage is accidentally applied, degauss the ratiotran as outlined in the Maintenance Instruction Book.

3-16. Make certain that the amplitude of the reference input voltage does not exceed 125 vrms, particularly at the lower frequencies. Do not apply a reference voltage to the bridge whose amplitude exceeds 0.35 times the frequency in cps.

3-17. Make certain the pre-operation adjustments are repeated whenever the frequency or amplitude of the reference input changes. If variations of ±3 digits in the in-phase accuracy (last place) and ±30 digits in the quadrature accuracy (last two places) are not critical to the test, minor variations in the reference voltage may be ignored.

3-18. With the FUNCTION switch in the 10° ANGLE position, considerable interaction between the two ratiotrans can exist. To simplify the nulling process, first obtain the in-phase and quadrature nulls in one of the rectangle positions, then turn the FUNCTION switch to the 10° angle position and repeat the quadrature null procedure.

3-19. Keep test connection leads as short as possible. Because of the nulling process and the guard vector circuit, length in the signal lead is not as critical as in the reference lead. A six foot length of No. 26 wire in the reference lead will cause a six digit error in the last decade (six parts per million). Because of the high resolution of the instrument, stray capacities and resistance of leads become important factors.

3-20. Always null out the quadrature component even if the quadrature ratio is not required. The quadrature component can overload the null amplifier and obscure the in-phase null. Since the gain of the null amplifier is very high, even a very small quadrature component can result in much reduced sensitivity. Assume an output vector voltage of 100 vrms and a phase shift of .01°. The sine of .01° is .00017. 100 x .00017 results in a quadrature component of 17 mv, but quadrature components as low as 800 uv will obscure the in-phase null.

3-21. Distortion or noise in the reference voltage can cause erroneous readings. Although the bridge will operate satisfactorily with a distorted reference voltage, the distortion may have a different effect on the unit under test than on the bridge reference circuitry. One result could be apparent phase shift.

TABLE III. PHASE ANGLE QUADRANT

SWITCH POSITION 0° - 180°	SWITCH POSITION 90° - 270°	RX Value	RjY Value	QUADRANT	ACTUAL PHASE ANGLE
0°	90°	+	+	1	$0° + \Theta$
180°	90°	-	+	2	$180° - \Theta$
180°	270°	-	-	3	$180° + \Theta$
0°	270°	+	-	4	$360° - \Theta$

SECTION IV
THEORY OF OPERATION

4-1. GENERAL THEORY. (See figure 4-1.)

4-2. If there is phase shift through a unit under test, the output signal as related to the input signal contains two components: an in-phase component (X) and a quadrature component (jY) (See figure 4-2). The amplitude of each component can be expressed as a ratio (R) between input and output signals. If the ratios of both components are known, they represent the rectangular coordinates of the output signal. From the rectangular coordinates, both amplitude and phase angle (Θ) of the output signal can be determined.

4-3. As shown in figure 4-3, the complex ratio bridge uses the reference voltage to generate an internal voltage which is exactly equal to the output signal of the unit under test. The reference voltage is applied directly across the in-phase ratiotran which produces the in-phase component of the internal voltage. The quadrature component is obtained in the same manner except that a quadrature generator is used to shift the phase of thereference voltage by 90°. The two components are summed in the quadrature injection transformer and applied to the chassis of the isolation amplifier.

4-4. The chassis of the isolation amplifier is completely floating and functions as the common for the input signal. When the internal voltage is exactly equal to the signal input, no potential exists between the input terminal and the chassis. Therefore the output of the isolation amplifier is minimum or null. The output of the isolation amplifier is applied to the null detector through the null amplifier. The null amplifier combines high gain, for detection of minute off-null voltages, with limiting, to protect the instrument against large off-null voltages. The tuned preamplifier portion of the null amplifier reduces the noise and harmonic content of the null signal.

4-5. The phase-sensitive null detector compares the output signal of the probe amplifier to a reference signal from the reference amplifier. With the IN-PHASE-QUADRATURE switch in the IN-PHASE position, an in-

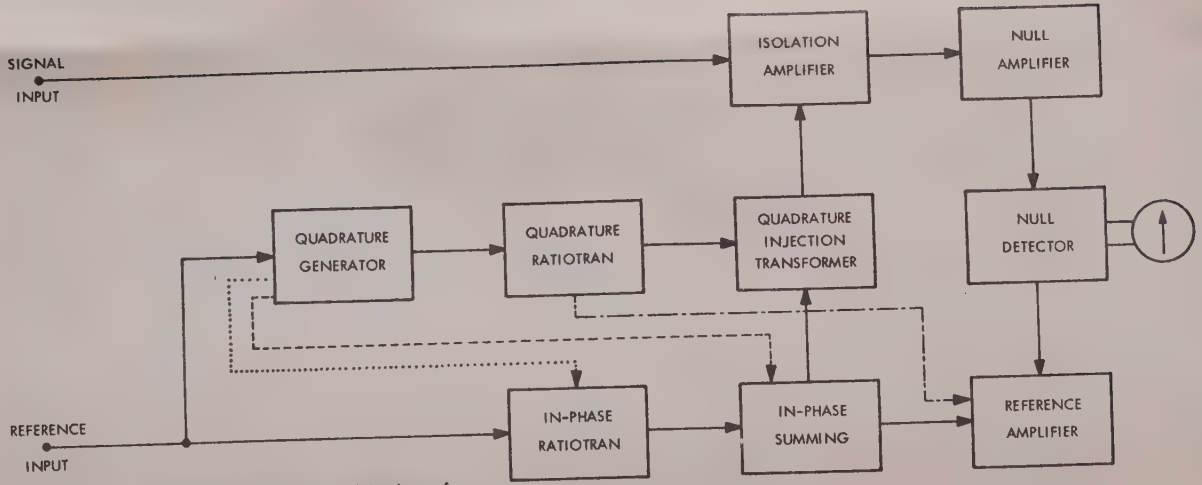

Figure 4-1. Overall Block Diagram

phase signal is supplied to the null detector through the reference amplifier. The null detector is sensitive only to the in-phase component of the probe amplifier output and detects a null when the two signals are 90° out-of-phase or when either input signal is at zero.

4-6. Assuming the input signal to be 10° out-of-phase with the reference voltage and the internal voltage to be zero, the null detector will detect an in-phase component. As the in-phase ratiotran is adjusted to apply an increasing in-phase component to the probe amplifier chassis, the resultant signal from the probe amplifier contains less and less in-phase component. When the in-phase component of the internal voltage exactly equals the in-phase component of the input signal, the resultant signal contains only a quadrature component. This resultant signal is applied to one side of the null detector. Since the two signals into the null detector are exactly 90° out-of-phase, the meter indicates a null.

4-7. The amount of in-phase voltage required to achieve a null is indicated by setting of the IN-PHASE ratio controls. The ratiotran consists of six transformer windings and each winding is controlled by an 11 position switch.

4-8. When the IN-PHASE-QUADRATURE switch is turned to the QUADRATURE position, the detector is sensitive to the quadrature portion. The quadrature ratiotran consists of five transformer windings controlled by five switches.

4-9. HIGH RECTANGLE MEASUREMENTS. (See figure 4-3.) In this position, the maximum voltage available for nulling out the quadrature component of the input signal is 50% of the reference voltage. The angle whose in-phase to quadrature ratio is 0.5 is approximately 25° (26.6°). The quadrature component is not direct reading in this position since the ratiotran is a decade device. The indicated ratio must be divided by two to obtain the actual ratio.

4-10. The full reference voltage is applied to the quadrature generator. The quadrature generator has a gain of 0.25 and its output is injected into the ratiotran at a 0.5 tap. The voltage available at the output of the ratiotran is therefore twice the input or 2 times 0.25. The output of the ratiotran is applied to the probe amplifier chassis through the 1:1 quadrature injection transformer.

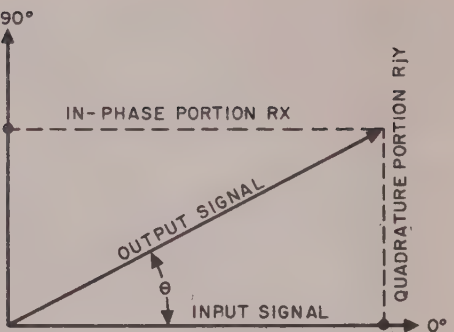

Figure 4-2. Input to Output Signal Relationships

4-11. LOW RECTANGLE MEASUREMENTS. (See figure 4-4.) In this position, the maximum voltage available for nulling out the quadrature component of the input signal is 10% of the reference voltage. The angle whose in-phase to quadrature ratio is 0.1 is approximately 5° (5.7°). In this position the quadrature component is direct reading.

4-12. The voltage applied to the quadrature generator is taken from a 0.4 tap on the in-phase ratiotran. 0.4 times the 0.25 gain of the quadrature generator equals 0.1. In this position, the output of the quadrature generator is injected across the full ratiotran.

4-13. 10° ANGLE MEASUREMENTS. (See figure 4-5.) A 10° angle has a tangent of 0.17633, that is $\frac{RjY}{RX} = 0.17633$. Assuming an in-phase ratio of 1.000000, the quadrature ratio for a 10° angle must be 0.176327. To obtain this injection ratio, the in-phase summing transformer is tapped at the 0.70532 point for the input to the quadrature generator. ($0.70532 \times 0.25 = 0.17633$.) Since the input voltage to the quadrature generator is taken from the in-phase ratiotran output, the $\frac{RjY}{RX}$ value is constant for any in-phase ratio.

4-14. A study of trigonometric tables will show that the tangent function is approximately linear from near zero to 10°. Therefore the decade steps of the quadrature ratiotran are approximately equal to the angular steps.

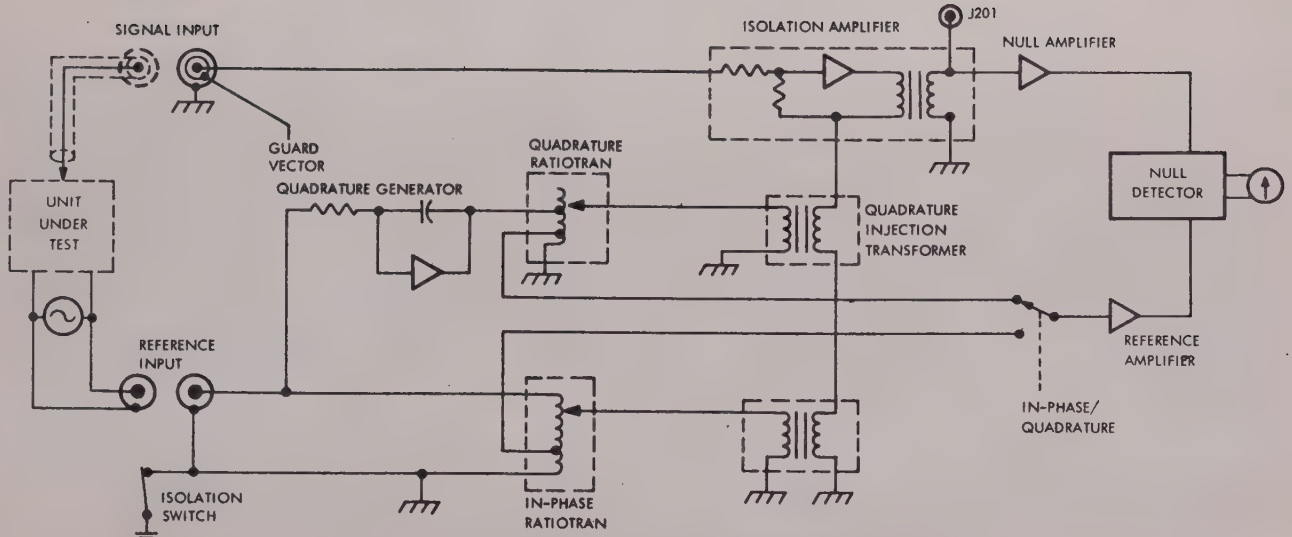

Figure 4-3. Simplified Block Diagram, High Rectangle Measurements

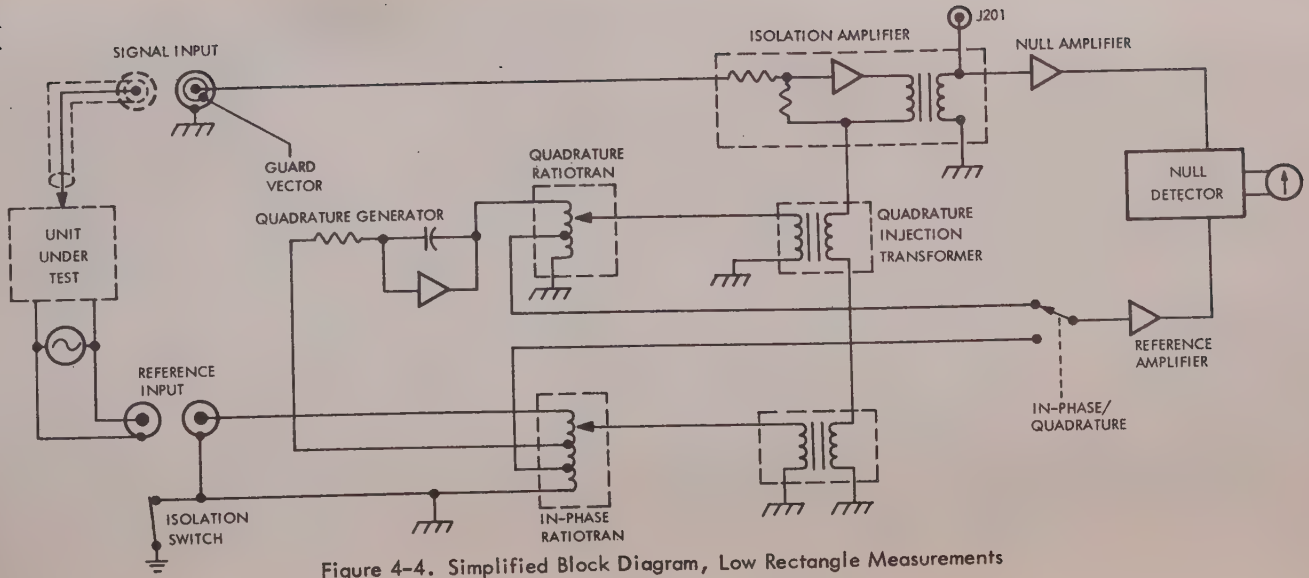

Figure 4-4. Simplified Block Diagram, Low Rectangle Measurements

4-15. REFERENCE LEVEL ADJUSTMENT. (See figure 4-6.) During operation, the reference amplifier receives a fixed portion of the reference voltage (0.1) from either the in-phase or quadrature ratiotran. For proper operation, the null detector must receive a reference voltage of constant amplitude but the input reference voltage may vary over a wide range. To provide a constant amplitude output, the gain of the reference amplifier is adjusted. The required gain is inversely proportional to the amount of input reference voltage and is obtained by controlling the amount of feedback.

4-16. When the FUNCTION switch is turned to the REF position, the meter is switched out of the null detector circuit and into a calibrated voltmeter circuit. The rectified, peak-to-peak output of the reference amplifier is compared to a fixed voltage supplied by the meter calibrator circuit. The REFERENCE LEVEL switch and vernier potentiometer adjust the feedback so that the amplifier supplies a voltage exactly equal to the calibrator voltage. When the two voltages are equal, the meter indicates a null.

4-17. QUADRATURE LEVEL ADJUSTMENT. (See figure 4-7.) For proper operation, the amplitude of the voltage supplied to the quadrature ratiotran must be in a precise proportion to the input reference voltage. Since the output of the quadrature generator will vary with frequency, a level adjustment is provided.

4-18. When the FUNCTION switch is turned to the QUAD position, the output of the quadrature generator is applied to the reference amplifier. The QUADRATURE LEVEL switch and vernier potentiometer adjust the output of the quadrature generator to exactly equal the in-phase reference signal. When the output of the quadrature generator is properly adjusted, the meter will indicate a null.

4-19. NULL AMPLIFIER PHASING ADJUSTMENT. (See figure 4-8.) Any inherent phase shift through the null amplifier can obscure null points. Since the amplifier must operate over a wide frequency range, a means of eliminating inherent phase shift is provided.

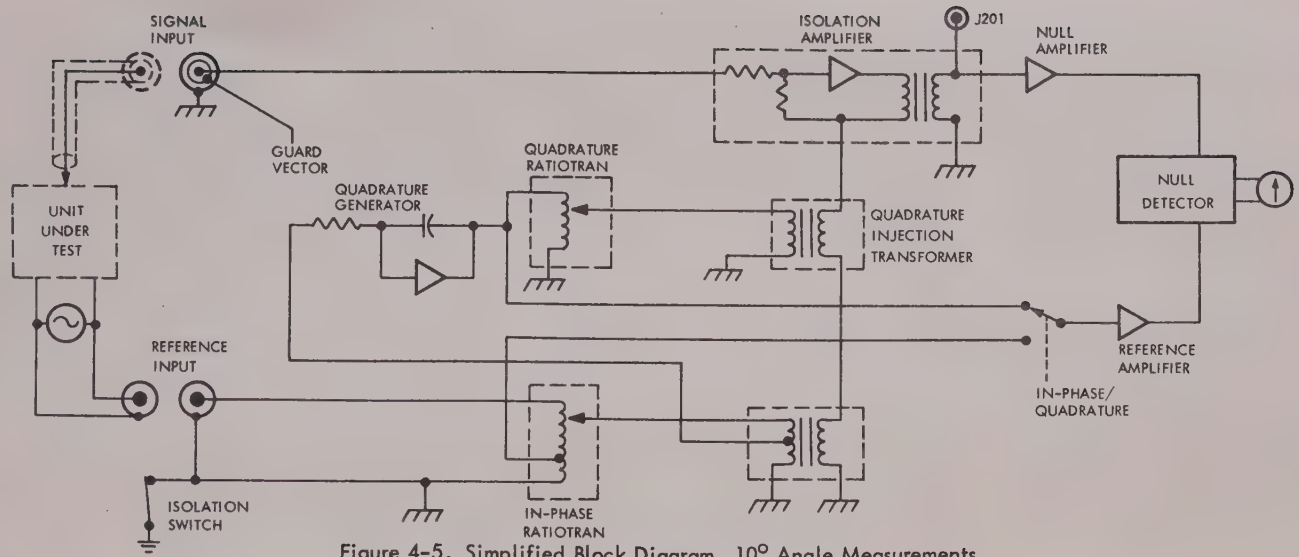

Figure 4-5. Simplified Block Diagram, 10° Angle Measurements

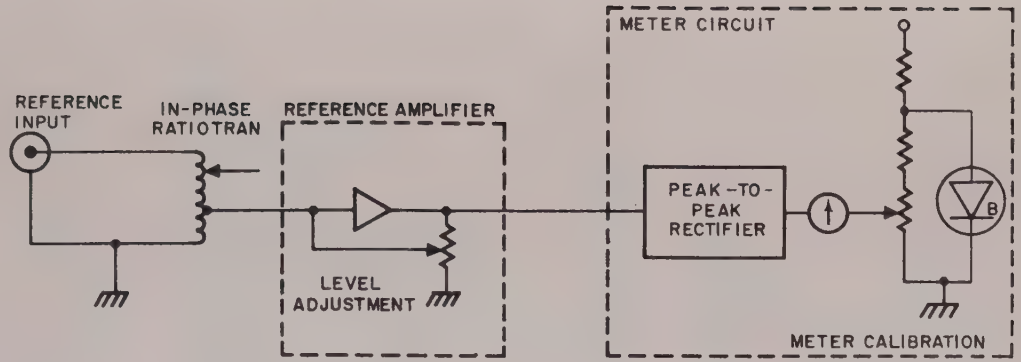

Figure 4-6. Reference Level Adjustment Circuit

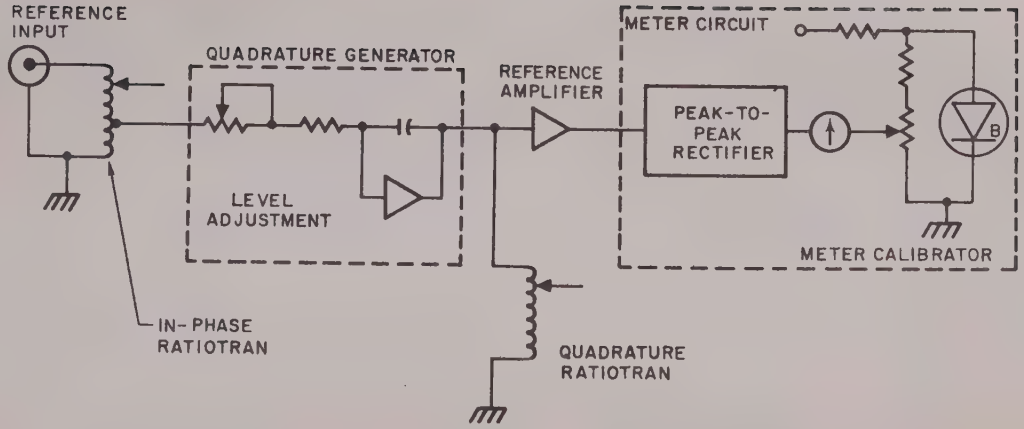

Figure 4-7. Quadrature Level Adjustment Circuit

4-20. When the FUNCTION switch is turned to the PHASING position, a small in-phase signal (500 uv) is applied to the probe amplifier and a quadrature reference voltage is applied to the null detector. Since the two signals should be exactly 90° out-of-phase, any voltage detected by the null detector represents phase shift through the signal channel. The PHASING switch and vernier control adjust the tuning of the null amplifier to eliminate phase shift. When the phase shift is eliminated, the input signals to the null detector are exactly 90° out-of-phase and the meter indicates a null.

4-21. The phasing signal must be small to avoid overdriving the null amplifier and yet large enough to provide a detectable output for any phase shift. Since the input reference voltage may vary, a separate section of the REFERENCE LEVEL switch is used to apply varying amounts of attenuation to the phasing signal.

4-22. UNITY CAL IN-PHASE ADJUSTMENT. (See figure 4-9.) Over the frequency range, the gain characteristics of the summing circuit can vary sufficiently to cause erroneous readings. To equalize the gain, the in-phase summing circuitry includes a means for adjusting the output of the in-phase ratiotran.

4-23. With the FUNCTION switch in the UNITY CAL IN-PHASE position, the full reference voltage is applied to the isolation amplifier input, the 1.000000 output of the in-phase ratiotran is applied to the chassis, and an in-phase signal is applied to the null detector. The two signals applied to the probe amplifier should be exactly equal and therefore any voltage detected by the null detector represents variations in gain characteristics. The UNITY CAL IN-PHASE switch and vernier control adjust the output of the in-phase ratiotran to exactly the input signal to the isolation amplifier. When the two signals are exactly equal, the meter will indicate a null.

4-24. UNITY CAL QUADRATURE ADJUSTMENT. (See figure 4-10.) As with the gain characteristics, the phase characteristics of the summing circuit can vary over the frequency range. To equalize phase characteristics, a means is provided to adjust the phase of the output signal from the in-phase ratiotran.

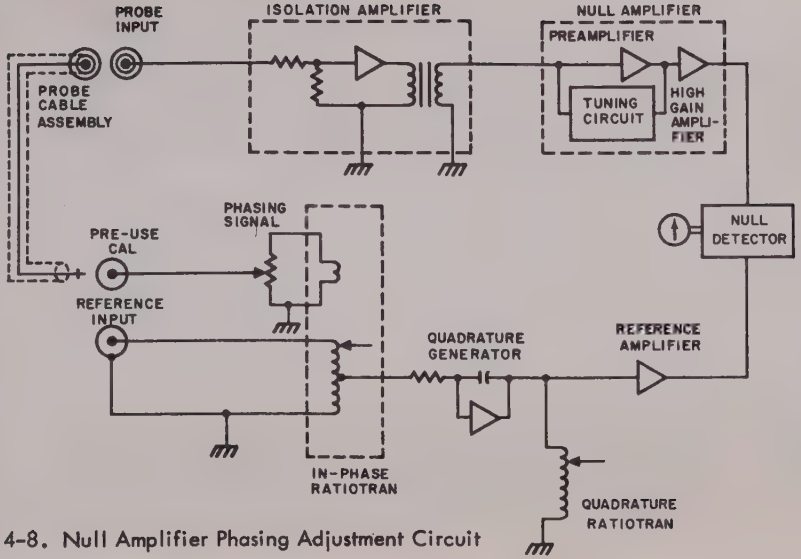

Figure 4-8. Null Amplifier Phasing Adjustment Circuit

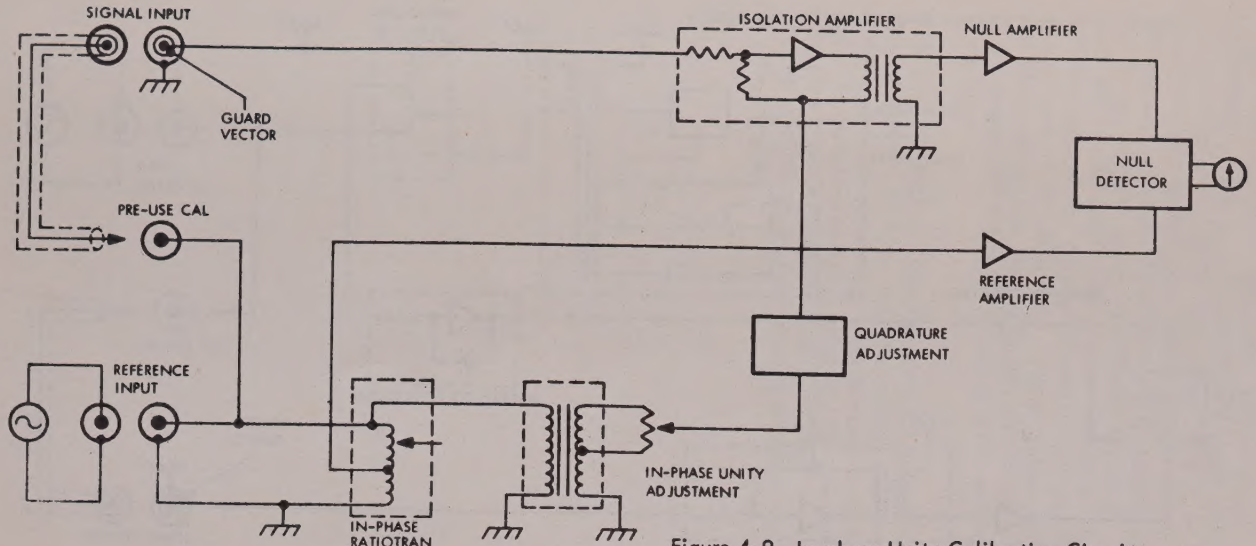

Figure 4-9. In-phase Unity Calibration Circuit

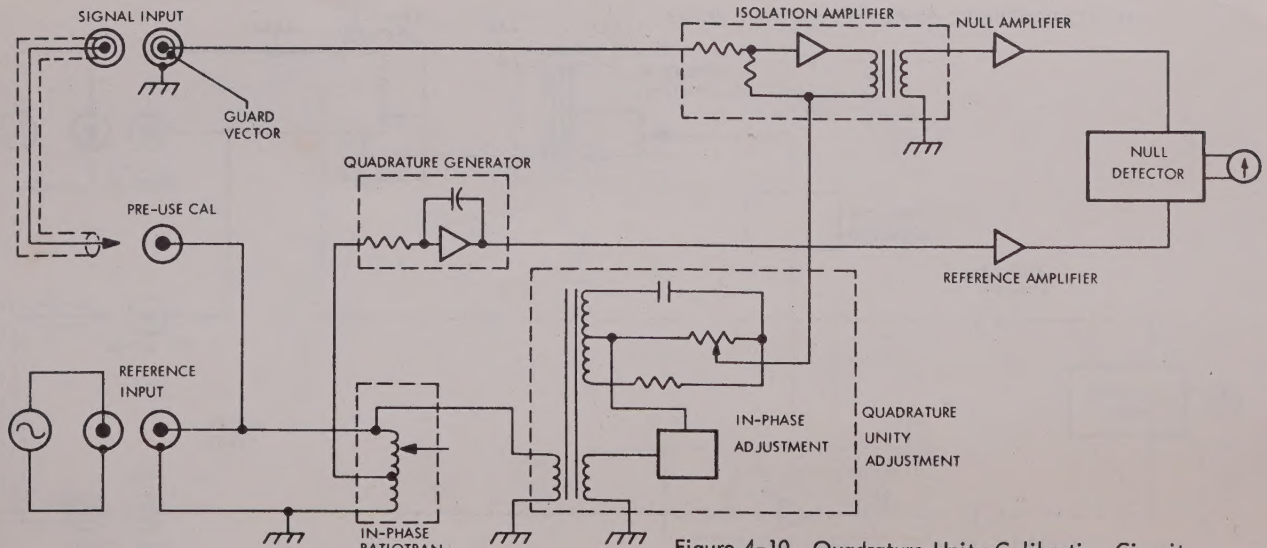

Figure 4-10. Quadrature Unity Calibration Circuit

4-25. When the FUNCTION switch is turned to the QUAD position, the circuit is the same as the in-phase circuit except that a quadrature reference voltage is supplied to the null detector. The two signals to the null detector should be 90° out-of-phase and therefore any voltage detected by the null detector represents phase shift in the input circuit. The potentiometer adjusts the output of the in-phase ratiotran to compensate for any input circuit phase shift. When the phase shift is compensated for, the two signals into the null detector are exactly 90° out-of-phase and the meter will indicate a null.

4-26. GUARD VECTOR. (See figure 4-11.) Capacitive coupling between the inner and outer conductors of the signal input or internal voltage leads can cause loading errors. To minimize capacitive coupling, the outer conductors are driven by a separate internal voltage. At null, the inner and outer conductors are at approximately the same potential.

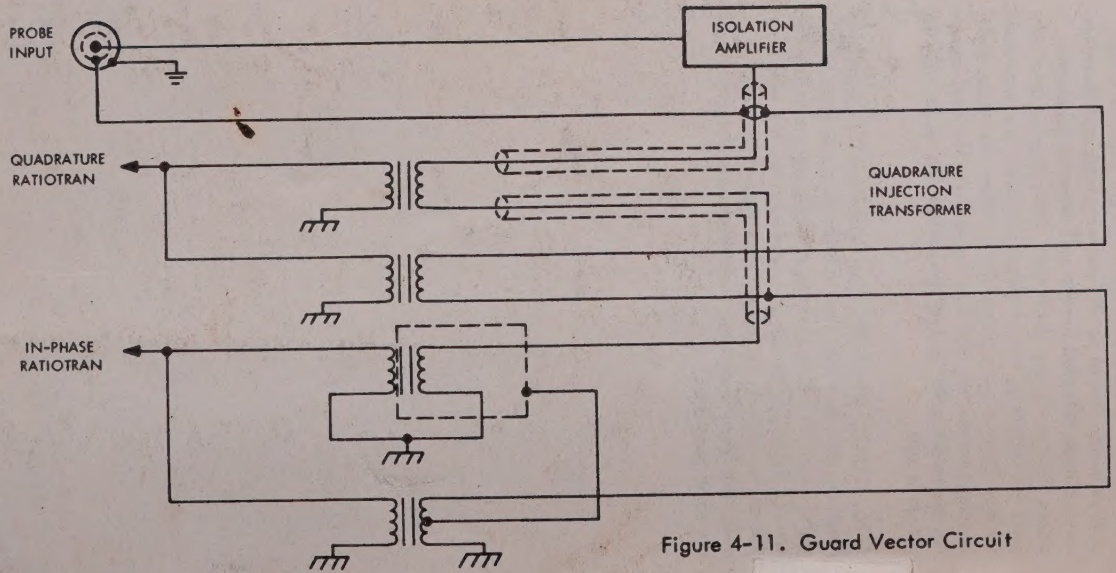

Figure 4-11. Guard Vector Circuit